Distribution Test Feeders 10-17

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In this document you can find applicable data for distribution test networks from various papers.

1- Multi-feeder 16 nodes distributuin network[1]

The three-feeder distribution netwotk is shown in below.

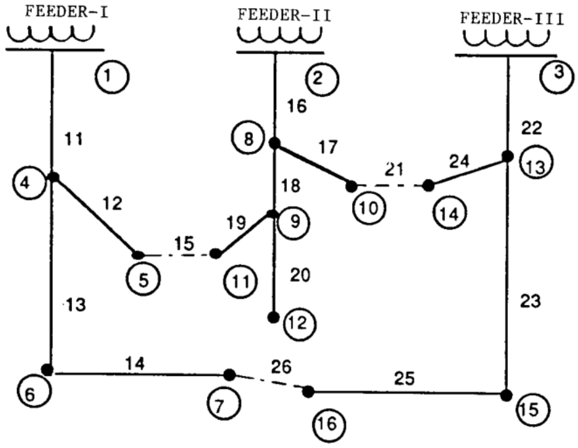


Figure 2 Three-feeder example system

The data of network is shown here.

Table 1 Data of the three-feeder example system

Bus to Bus	Section Resistance (P.U)	Section Reactance (P.U)	End Bus Load (MW)	End Bus Load (MVAR)	End Bus Capacitor (MVAR)	End Bus Voltage (P.U)
1-4	0.075	0.1	2.0	1.6		0.991/-0.370
4-5	0.08	0.11	3.0	1.5	1.1	0.988/-0.544
4-6	0.09	0.18	2.0	0.8	1.2	0.986/-0.697
6-7	0.04	0.04	1.5	1.2		0.985/-0.704
2-8	0.11	0.11	4.0	2.7		0.979/-0.763
8-9	0.08	0.11	5.0	3.0	1.2	0.971/-1.451
8-10	0.11	0.11	1.0	0.9		0.977/-0.770
9-11	0.11	0.11	0.6	0.1	0.6	0.971/-1.525
9-12	0.08	0.11	4.5	2.0	3.7	0.969/-1.836
3-13	0.11	0.11	1.0	0.9		0.994/-0.332
13-14	0.09	0.12	1.0	0.7	1.8	0.995/-0.459
13-15	0.08	0.11	1.0	0.9		0.992/-0.527
15-16	0.04	0.04	2.1	1.0	1.8	0.991/-0.596
5-11	0.04	0.04				
10-14	0.04	0.04				
7-16	0.09	0.12				

[1] Distribution Feeder Reconfiguration for Loss Reduction

2- 18-bus Grady test feeder[٢]

The new optimization procedure is illustrated using the 18 bus balanced three-phase system shown in Figure 1. This system contains 16 busses at 12.5 kV, and 2 busses (#50 and #51) at 138 kV. A 3.0 MW, 2.6 MVAr six-pulse line commutated converter, located at bus 5, serves as a source of harmonics. The task is to simulate the effect of a three-phase APLC on the 12.5 kV network [apf02, apf03].

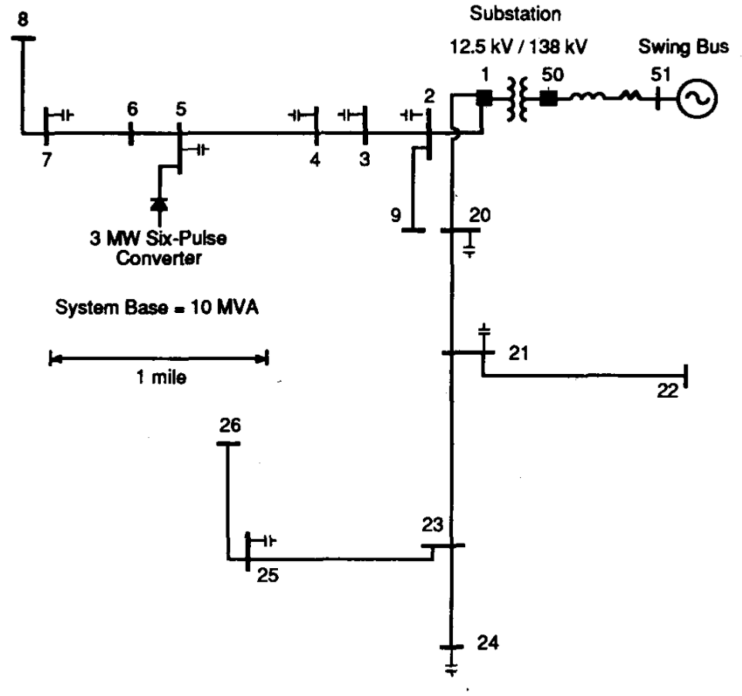


Figure 1: 18 Bus Example System

H = 25, and calculation is down through 25th harmonic. S_{base} = 10 MVA.

Bus data:

Number		Name	Type	P gen (%)	Q gen (%)	S VA (%)	P load (%)	Q load (%)	Voltage	Shunt load (%)
1	3	gar12.5	3	0	0	0	0	0	0	0
2	4	cap1-2	3	0	0	0	2	1.2	0	-10.5
3	5	cap4	3	0	0	0	5	2.5	0	-6
4	6	cap3	3	0	0	0	15	9.3	0	-6
5	7	sixpulse	23	0	0	0	30	22.6	0	-18
6	8	six	3	0	0	0	8	5	0	0
7	9	cap6	3	0	0	0	2	1.2	0	-6
8	10	eight	3	0	0	0	10	6.2	0	0
9	11	nine	3	0	0	0	5	3.1	0	0
20	12	cap7	3	0	0	0	10	6.2	0	-6
21	13	cap8-9	3	0	0	0	3	1.9	0	-12
22	14	bus22	3	0	0	0	2	1.2	0	0
23	15	bus23	3	0	0	0	8	5	0	0
24	16	cap10-	3	0	0	0	5	3.1	0	-15

[٢] Grady, W. M., M. J. Samotyj, and A. H. Noyola. "Minimizing network harmonic voltage distortion with an active power line conditioner." *Power Delivery, IEEE Transactions on* 6, no. 4 (1991): 1690-1697

		11								
25	17	cap12	3	0	0	0	10	6.2	0	-9
26	18	bus26	3	0	0	0	2	1.2	0	0
50	2	gar138	3	0	0	0	0	0	0	-12
51	1	swing	1	0	0	0	0	0	105.0	0

Line Data:

Number		To	From	R [+] (%)	X [+] (%)	Charge (%)	Length (mi)	Base Imp (Ω)	Harm Only
1	3	1	2	0.431	1.204	0.0035	0.318	15.625	0
2	4	2	3	0.601	1.677	0.0049	0.443	15.625	0
3	5	3	4	0.316	0.882	0.0026	0.233	15.625	0
4	6	4	5	0.896	2.502	0.0073	0.661	15.625	0
5	7	5	6	0.295	0.824	0.0024	0.218	15.625	0
6	8	6	7	1.720	2.120	0.0046	0.455	15.625	0
7	9	7	8	4.070	3.053	0.0051	0.568	15.625	0
8	10	2	9	1.706	2.209	0.0043	0.451	15.625	0
9	11	1	20	2.910	3.768	0.0074	0.769	15.625	0
10	12	20	21	2.222	2.877	0.0056	0.587	15.625	0
11	13	21	22	4.803	6.218	0.0122	1.269	15.625	0
12	14	21	23	3.985	5.160	0.0101	1.053	15.625	0
13	15	23	24	2.910	3.768	0.0074	0.769	15.625	0
14	16	23	25	3.727	4.593	0.0100	0.985	15.625	0
15	17	25	26	2.208	2.720	0.0059	0.583	15.625	0
16	2	50	1	0.312	6.573	0	0	0	0
17	1	50	51	0.050	0.344	0	0	0	0
18		51	0	0.000	0.010	0	0	0	1

Nonlinear bus data:

Bus	R (%)	X - DC circuit (% @ 60Hz)	X Transformer (% @ 60Hz)	Type
5	2.26	226.0	20.45	1

3- 29-bus radial distribution network[۲]

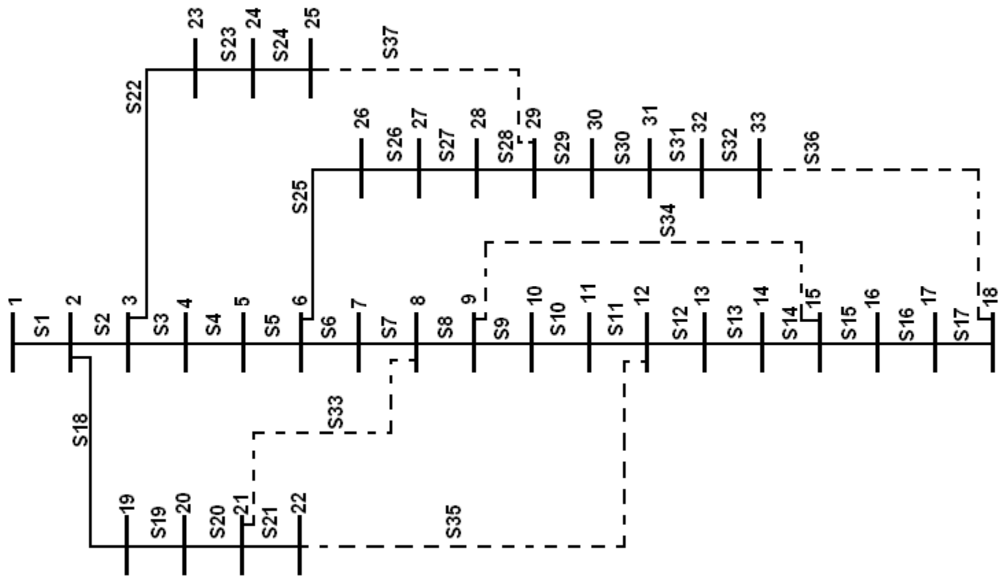
One may draw the netwotk diagram. Vb = 11 kV, Sb = 100 MVA.

Branch number	Sending end	Receiving end	R(Ω)	X(Ω)	*P* @ receiving end node (kW)	*Q* @ receiving end node (kVAr)
1	1	2	1.8216	0.7580	140.00	90.00
2	2	3	2.2270	0.9475	80.00	50.00
3	3	4	1.3662	0.5685	80.00	60.00
4	4	5	0.9180	0.3790	100.00	60.00
5	5	6	3.6432	1.5160	80.00	50.00
6	6	7	2.7324	1.1370	90.00	40.00
7	7	8	1.4573	0.6064	90.00	40.00
8	8	9	2.7324	1.1370	80.00	50.00
9	9	10	3.6432	1.5160	90.00	50.00
10	10	11	2.7520	0.7780	80.00	50.00
11	11	12	1.3760	0.3890	80.00	40.00
12	12	13	4.1280	1.1670	90.00	50.00
13	13	14	4.1280	0.8558	70.00	40.00
14	14	15	3.0272	0.7780	70.00	40.00
15	15	16	2.7520	1.1670	70.00	40.00
16	16	17	4.1280	0.7780	60.00	30.00
17	17	18	2.7520	0.7780	60.00	30.00
18	2	19	3.4400	0.9725	70.00	40.00
19	19	20	1.3760	0.3890	50.00	30.00
20	20	21	2.7520	0.7780	50.00	30.00
21	21	22	4.9536	1.4004	40.00	20.00
22	3	23	3.5776	1.0114	50.00	30.00
23	23	24	3.0272	0.8558	50.00	20.00
24	24	25	5.5040	1.5560	60.00	30.00
25	6	26	2.7520	0.7780	40.00	20.00
26	26	27	1.3760	0.3890	40.00	20.00
27	27	28	1.3760	0.3890	40.00	20.00

[۲] Method for load-flow solution of radial distribution networks (dpf)

4- 33-bus distribution network[4].

System diagram.



System Data. Vb = 12.66 kV and Sb = 10 MVA.

Number	From	To	Resis. (Ω)	Reac. (Ω)	Nominal Load at Receiving Bus	
					P (kW)	Q (kVAr)
1	1	2	0.0922	0.047	100	60
2	2	3	0.493	0.2511	90	40
3	3	4	0.366	0.1864	120	80
4	4	5	0.3811	0.1941	60	30
5	5	6	0.819	0.707	60	20
6	6	7	0.1872	0.6188	200	100
7	7	8	0.7114	0.2351	200	100
8	8	9	1.03	0.74	60	20
9	9	10	1.044	0.74	60	20
10	10	11	0.1966	0.065	45	30
11	11	12	0.3744	0.1298	60	35
12	12	13	1.468	1.155	60	35
13	13	14	0.5416	0.7129	120	80
14	14	15	0.591	0.526	60	10
15	15	16	0.7463	0.545	60	20
16	16	17	1.289	1.721	60	20

[4] Load Flow Analysis of Radial Distributtion Network using Linear Data Structure

17	17	18	0.732	0.574	90	40
18	2	19	0.164	0.1565	90	40
19	19	20	1.5042	1.3554	90	40
20	20	21	0.4095	0.4784	90	40
21	21	22	0.7089	0.9373	90	40
22	3	23	0.4512	0.3083	90	50
23	23	24	0.898	0.7091	420	200
24	24	25	0.896	0.7011	420	200
25	6	26	0.203	0.1034	60	25
26	26	27	0.2842	0.1447	60	25
27	27	28	1.059	0.9337	60	20
28	28	29	0.8042	0.7006	120	70
29	29	30	0.5075	0.2585	200	600
30	30	31	0.9744	0.963	150	70
31	31	32	0.3105	0.3619	210	100
32	32	33	0.341	0.5302	60	40

5- 69-bus radial distrbution network[Δ]

One-line duagram of system has shown here. Base voltage and base power are equal to 12.66 kV and 10 KVA respectively.

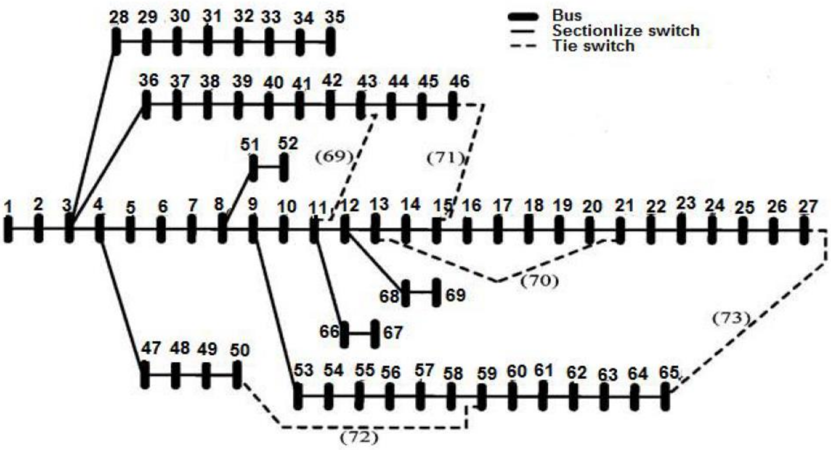


Fig. 4. The IEEE 69-bus distribution system.

System data are as follows.

Branch Number	Sending Bus	Receiving Bus	Resistance Ω	Reactance Ω	Nominal Load at Receiving Bus		Maximum Line Capacity (kVA)
					P (kW)	Q (kVAr)	
1	1	2	0.0005	0.0012	0.0	0.0	10761
2	2	3	0.0005	0.0012	0.0	0.0	10761
3	3	4	0.0015	0.0036	0.0	0.0	10761
4	4	5	0.0251	0.0294	0.0	0.0	5823
5	5	6	0.3660	0.1864	2.60	2.20	1899
6	6	7	0.3811	0.1941	40.40	30.00	1899
7	7	8	0.0922	0.0470	75.00	54.00	1899
8	8	9	0.0493	0.0251	30.00	22.00	1899
9	9	10	0.8190	0.2707	28.00	19.00	1455
10	10	11	0.1872	0.0619	145.00	104.00	1455
11	11	12	0.7114	0.2351	145.00	104.00	1455
12	12	13	1.0300	0.3400	8.00	5.00	1455
13	13	14	1.0440	0.3450	8.00	5.50	1455
14	14	15	1.0580	0.3496	0.0	0.0	1455
15	15	16	0.1966	0.0650	45.50	30.00	1455
16	16	17	0.3744	0.1238	60.00	35.00	1455
17	17	18	0.0047	0.0016	60.00	35.00	2200
18	18	19	0.3276	0.1083	0.0	0.0	1455
19	19	20	0.2106	0.0690	1.00	0.60	1455
20	20	21	0.3416	0.1129	114.00	81.00	1455
21	21	22	0.0140	0.0046	5.00	3.50	1455
22	22	23	0.1591	0.0526	0.0	0.0	1455
23	23	24	0.3463	0.1145	28.00	20.0	1455
24	24	25	0.7488	0.2475	0.0	0.0	1455
25	25	26	0.3089	0.1021	14.0	10.0	1455
26	26	27	0.1732	0.0572	14.0	10.0	1455
27	3	28	0.0044	0.0108	26.0	18.6	10761

[Δ] Load Flow Analysis of Radial Distributtion Network using Linear Data Structure

28	28	29	0.0640	0.1565	26.0	18.6	10761
29	29	30	0.3978	0.1315	0.0	0.0	1455
30	30	31	0.0702	0.0232	0.0	0.0	1455
31	31	32	0.3510	0.1160	0.0	0.0	1455
32	32	33	0.8390	0.2816	14.0	10.0	2200
33	33	34	1.7080	0.5646	9.50	14.00	1455
34	34	35	1.4740	0.4873	6.00	4.00	1455
35	3	36	0.0044	0.0108	26.0	18.55	10761
36	36	37	0.0640	0.1565	26.0	18.55	10761
37	37	38	0.1053	0.1230	0.0	0.0	5823
38	38	39	0.0304	0.0355	24.0	17.00	5823
39	39	40	0.0018	0.0021	24.0	17.00	5823
40	40	41	0.7283	0.8509	1.20	1.0	5823
41	41	42	0.3100	0.3623	0.0	0.0	5823
42	42	43	0.0410	0.0478	6.0	4.30	5823
43	43	44	0.0092	0.0116	0.0	0.0	5823
44	44	45	0.1089	0.1373	39.22	26.30	5823
45	45	46	0.0009	0.0012	39.22	26.30	6709
46	4	47	0.0034	0.0084	0.00	0.0	10761
47	47	48	0.0851	0.2083	79.00	56.40	10761
48	48	49	0.2898	0.7091	384.70	274.50	10761
49	49	50	0.0822	0.2011	384.70	274.50	10761
50	8	51	0.0928	0.0473	40.50	28.30	1899
51	51	52	0.3319	0.1114	3.60	2.70	2200
52	52	53	0.1740	0.0886	4.35	3.50	1899
53	53	54	0.2030	0.1034	26.40	19.00	1899
54	54	55	0.2842	0.1447	24.00	17.20	1899
55	55	56	0.2813	0.1433	0.0	0.0	1899
56	56	57	1.5900	0.5337	0.0	0.0	2200
57	57	58	0.7837	0.2630	0.0	0.0	2200
58	58	59	0.3042	0.1006	100.0	72.0	1455
59	59	60	0.3861	0.1172	0.0	0.0	1455
60	60	61	0.5075	0.2585	1244.0	888.00	1899
61	61	62	0.0974	0.0496	32.0	23.00	1899
62	62	63	0.1450	0.0738	0.0	0.0	1899
63	63	64	0.7105	0.3619	227.0	162.00	1899
64	64	65	1.0410	0.5302	59.0	42.0	1899
65	11	66	0.2012	0.0611	18.0	13.0	1455
66	66	67	0.0047	0.0014	18.0	13.0	1455
67	12	68	0.7394	0.2444	28.0	20.0	1455
68	68	69	0.0047	0.0016	28.0	20.0	1455
69*	11	43	0.5000	0.5000			566
70*	13	21	0.5	0.5			566
71*	15	46	1.0	1.0			400
72*	50	59	2.0	2.0			283
73*	27	65	1.0	1.0			400

6- 70-bus test feeder[ϟ]

The tested system is a 11-kV radial distribution system having two substations, four feeders, 70 nodes, and 78 branches (including tie branches) as shown in Fig. 9. Tie switches of this system are open in normal conditions. Data for this system are given in the Appendix.

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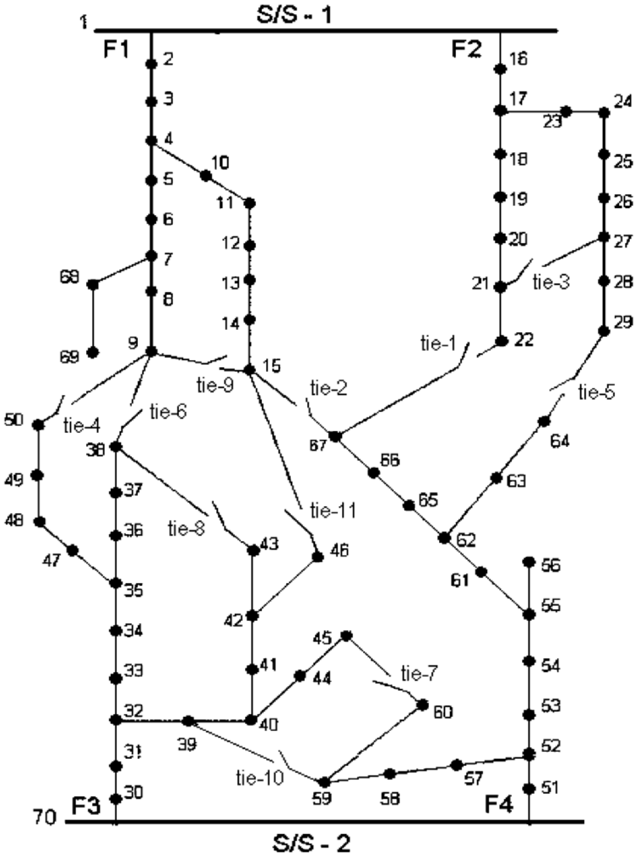


Other data: current carrying capacity of all tie branches are 234.0 A. The current carrying capacity of branches 1 to 8, 17 to 23, 31 to 39, and 52 to 57 is 270 A. For branches 9 to 16, 24 to 30, 40 to 51, and 58 to 68, it is 208 A (see Table III).

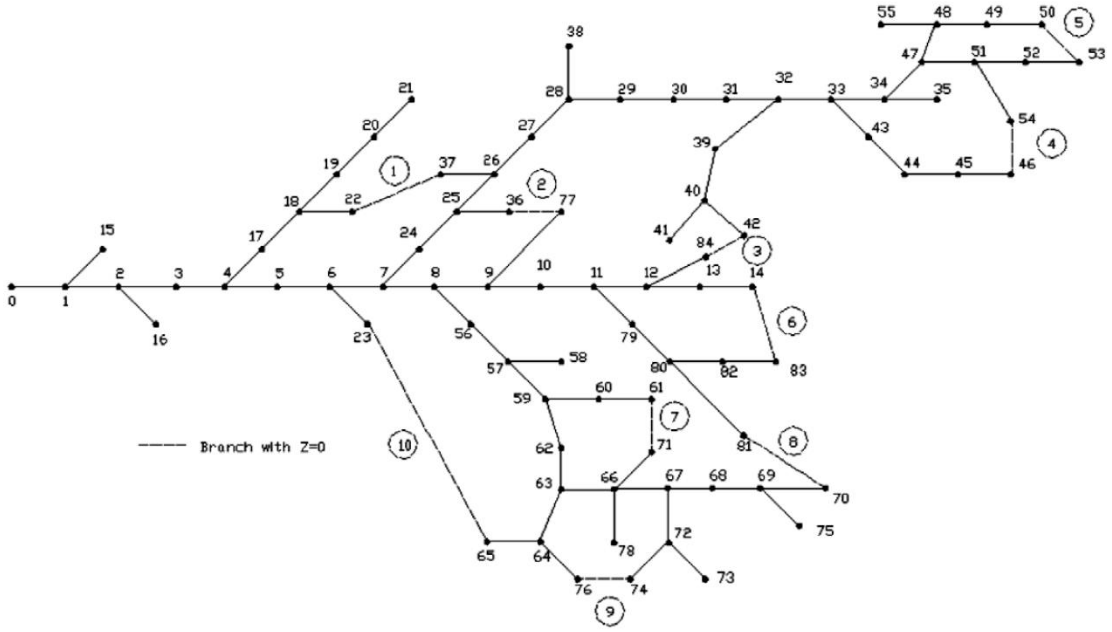
ϟ Das, Debapriya. "A fuzzy multiobjective approach for network reconfiguration of distribution systems." *Power Delivery, IEEE Transactions on* 21, no. 1 (2006): 202-209.

TABLE III
LINE AND LOAD DATA

Br. No. (i)	Send. end IS(i)	Recv. End IR(i)	R (ohm)	X (ohm)	PL(IR) (kW)	QL(IR) (kVAr)
1	1	2	1.097	1.074	100.0	90.0
2	2	3	1.463	1.432	60.0	40.0
3	3	4	0.731	0.716	150.0	130.0
4	4	5	0.366	0.358	75.0	50.0
5	5	6	1.828	1.790	15.0	9.0
6	6	7	1.097	1.074	18.0	14.0
7	7	8	0.731	0.716	13.0	10.0
8	8	9	0.731	0.716	16.0	11.0
9	4	10	1.080	0.734	20.0	10.0
10	10	11	1.620	1.101	16.0	9.0
11	11	12	1.080	0.734	50.0	40.0
12	12	13	1.350	0.917	105.0	90.0
13	13	14	0.810	0.550	25.0	15.0
14	14	15	1.944	1.321	40.0	25.0
15	7	68	1.080	0.734	100.0	60.0
16	68	69	1.620	1.101	40.0	30.0
17	1	16	1.097	1.074	60.0	30.0
18	16	17	0.366	0.358	40.0	25.0
19	17	18	1.463	1.432	15.0	9.0
20	18	19	0.914	0.895	13.0	7.0
21	19	20	0.804	0.787	30.0	20.0
22	20	21	1.133	1.110	90.0	50.0
23	21	22	0.475	0.465	50.0	30.0
24	17	23	2.214	1.505	60.0	40.0
25	23	24	1.620	1.110	100.0	80.0
26	24	25	1.080	0.734	80.0	65.0
27	25	26	0.540	0.367	100.0	60.0
28	26	27	0.540	0.367	100.0	55.0
29	27	28	1.080	0.734	120.0	70.0
30	28	29	1.080	0.734	105.0	70.0
31	70	30	0.366	0.358	80.0	50.0
32	30	31	0.731	0.716	60.0	40.0
33	31	32	0.731	0.716	13.0	8.0
34	32	33	0.804	0.787	16.0	9.0
35	33	34	1.170	1.145	50.0	30.0
36	34	35	0.768	0.752	40.0	28.0
37	35	36	0.731	0.716	60.0	40.0
38	36	37	1.097	1.074	40.0	30.0
39	37	38	1.463	1.432	30.0	25.0
40	32	39	1.080	0.734	150.0	100.0
41	39	40	0.540	0.367	60.0	35.0
42	40	41	1.080	0.734	120.0	70.0
43	41	42	1.836	1.248	90.0	60.0
44	42	43	1.296	0.881	18.0	10.0
45	40	44	1.188	0.807	16.0	10.0
46	44	45	0.540	0.367	100.0	50.0
47	42	46	1.080	0.734	60.0	40.0
48	35	47	0.540	0.367	90.0	70.0
49	47	48	1.080	0.734	85.0	55.0
50	48	49	1.080	0.734	100.0	70.0
51	49	50	1.080	0.734	140.0	90.0
52	70	51	0.366	0.358	60.0	40.0
53	51	52	1.463	1.432	20.0	11.0
54	52	53	1.463	1.432	40.0	30.0
55	53	54	0.914	0.895	36.0	24.0
56	54	55	1.097	1.074	30.0	20.0
57	55	56	1.097	1.074	43.0	30.0
58	52	57	0.270	0.183	80.0	50.0
59	57	58	0.270	0.183	240.0	120.0
60	58	59	0.810	0.550	125.0	110.0
61	59	60	1.296	0.881	25.0	10.0
62	55	61	1.188	0.807	10.0	5.0
63	61	62	1.188	0.807	150.0	130.0
64	62	63	0.810	0.550	50.0	30.0
65	63	64	1.620	1.101	30.0	20.0
66	62	65	1.080	0.734	130.0	120.0
67	65	66	0.540	0.367	150.0	130.0
68	66	67	1.080	0.734	25.0	15.0
			Tie-branch			
69	9	50	0.908	0.726	-	-
70	9	38	0.381	0.244	-	-
71	15	46	0.681	0.544	-	-
72	22	67	0.254	0.203	-	-
73	29	64	0.254	0.203	-	-
74	45	60	0.254	0.203	-	-
75	43	38	0.454	0.363	-	-
76	39	59	0.454	0.363	-	-
77	21	27	0.454	0.363	-	-
78	15	9	0.681	0.544	-	-
79	67	15	0.454	0.363	-	-

7- 85 bus test system[٧]

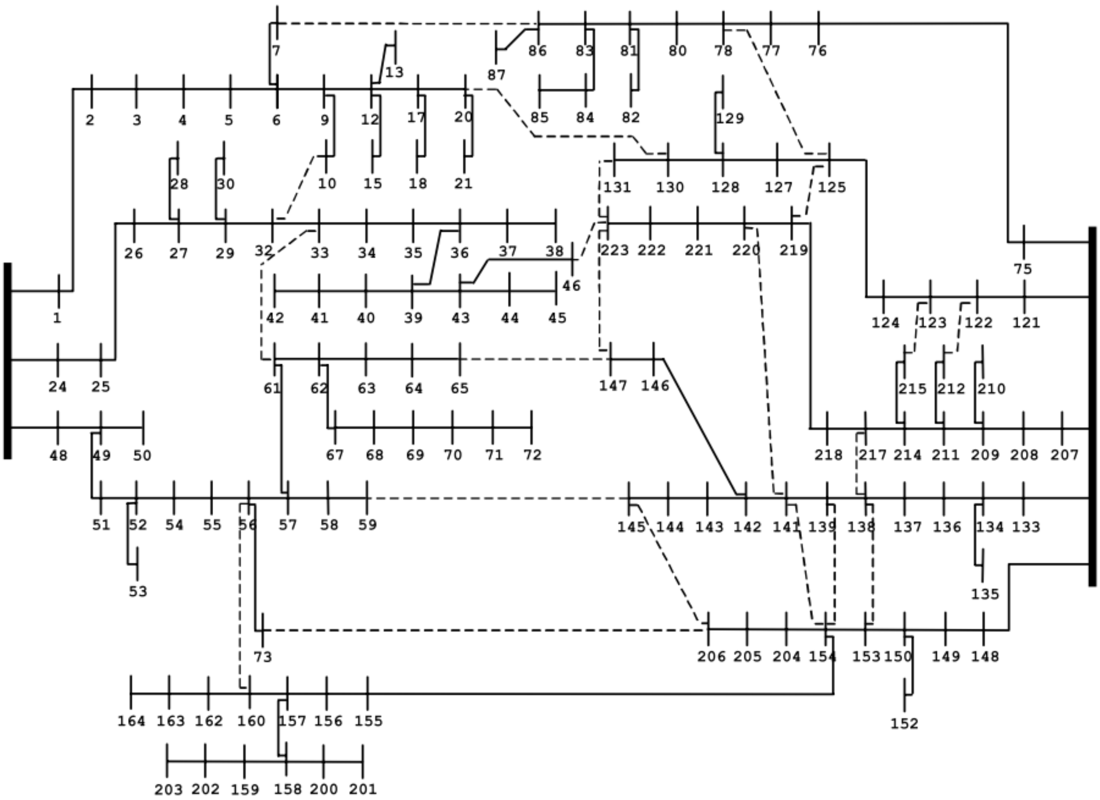
The diagram of system has shown below.



[٧] Simple and efficient method for load flow solution of radial distribution networks

8- 136-bus test system[A]

The diagram of this picture has shown in the below. The base volatge and base power are equal to 13.8 kV and 100 MVA, respectively.



Here are the data.

Line	From	To	R (Ω)	X (Ω)	P (kW)	Q (kVAr)
1	0	1	0.33205	0.76653	000.000	000.000
2	1	2	0.00188	0.00433	047.780	019.009
3	2	3	0.22324	0.51535	042.551	016.929
4	3	4	0.09943	0.22953	087.022	034.622
5	4	5	0.15571	0.35945	311.310	123.855
6	5	6	0.16321	0.37677	148.869	059.228
7	6	7	0.11444	0.26417	238.672	094.956
8	6	9	0.05675	0.05666	062.299	024.786
9	9	10	0.52124	0.27418	124.598	049.571
10	9	12	0.10877	0.10860	140.175	055.768
11	12	13	0.39803	0.20937	116.813	046.474
12	12	15	0.91744	0.31469	249.203	099.145
13	12	17	0.11823	0.11805	291.447	115.952
14	17	18	0.50228	0.26421	303.720	120.835
15	17	20	0.05675	0.05666	215.396	085.695
16	20	21	0.29379	0.15454	198.586	079.007
17	0	24	0.33205	0.76653	000.000	000.000
18	24	25	0.00188	0.00433	000.000	000.000
19	25	26	0.22324	0.51535	000.000	000.000

[A] Mantovani, José RS, Fernando Casari, and Rubén A. Romero. "Reconfiguração de sistemas de distribuição radiais utilizando o critério de queda de tensão." *Controle and Automacao* (2000): 150-159.

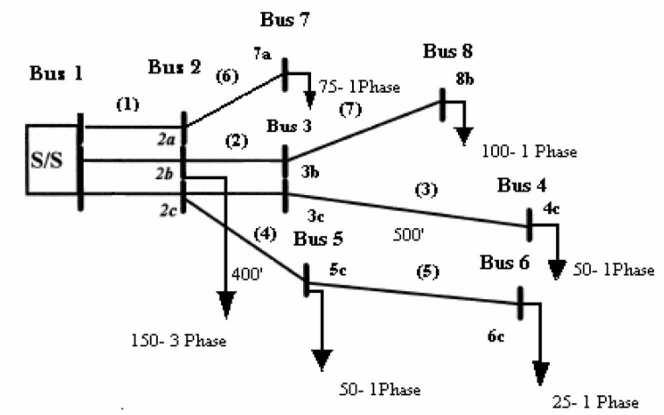
20	26	27	0.10881	0.25118	030.127	014.729
21	27	28	0.71078	0.37388	230.972	112.920
22	27	29	0.18197	0.42008	060.256	029.458
23	29	30	0.30326	0.15952	230.972	112.920
24	29	32	0.02439	0.05630	120.507	058.915
25	32	33	0.04502	0.10394	000.000	000.000
26	33	34	0.01876	0.04331	056.981	027.857
27	34	35	0.11823	0.11805	364.665	178.281
28	35	36	0.02365	0.02361	000.000	000.000
29	36	37	0.18954	0.09970	124.647	060.939
30	37	38	0.39803	0.20937	056.981	027.857
31	36	39	0.05675	0.05666	000.000	000.000
32	39	40	0.09477	0.04985	085.473	041.787
33	40	41	0.41699	0.21934	000.000	000.000
34	41	42	0.11372	0.05982	396.735	193.960
35	39	43	0.07566	0.07555	000.000	000.000
36	43	44	0.36960	0.19442	181.152	088.563
37	44	45	0.26536	0.13958	242.172	118.395
38	43	46	0.05675	0.05666	075.316	036.821
39	0	48	0.33205	0.76653	000.000	000.000
40	48	49	0.11819	0.27283	001.254	000.531
41	49	50	2.96288	1.01628	006.274	002.660
42	49	51	0.00188	0.00433	000.000	000.000
43	51	52	0.06941	0.16024	117.880	049.971
44	52	53	0.81502	0.42872	062.668	026.566
45	52	54	0.06378	0.14724	172.285	073.034
46	54	55	0.13132	0.30315	458.556	194.388
47	55	56	0.06191	0.14291	262.962	111.473
48	56	57	0.11444	0.26417	235.761	099.942
49	57	58	0.28374	0.28331	000.000	000.000
50	58	59	0.28374	0.28331	109.215	046.298
51	57	61	0.04502	0.10394	000.000	000.000
52	61	62	0.02626	0.06063	072.809	030.865
53	62	63	0.06003	0.13858	258.473	109.570
54	63	64	0.03002	0.06929	069.169	029.322
55	64	65	0.02064	0.04764	021.843	009.260
56	62	67	0.10881	0.25118	000.000	000.000
57	67	68	0.25588	0.13460	020.527	008.702
58	68	69	0.41699	0.21934	150.548	063.819
59	69	70	0.50228	0.26421	220.687	093.552
60	70	71	0.33170	0.17448	092.384	039.163
61	71	72	0.20849	0.10967	000.000	000.000
62	56	73	0.13882	0.32047	226.693	096.098
63	0	75	0.00750	0.01732	000.000	000.000
64	75	76	0.27014	0.62362	294.016	116.974
65	76	77	0.38270	0.88346	083.015	033.028
66	77	78	0.33018	0.76220	083.015	033.028
67	78	80	0.32830	0.75787	103.770	041.285
68	80	81	0.17072	0.39409	176.408	070.184
69	81	82	0.55914	0.29412	083.015	033.028
70	81	83	0.05816	0.13425	217.917	086.698
71	83	84	0.70130	0.36890	023.294	009.267
72	84	85	1.02352	0.53839	005.075	002.019
73	83	86	0.06754	0.15591	072.638	028.899
74	86	87	1.32352	0.45397	405.990	161.523

75	0	121	0.01126	0.02598	000.000	000.000
76	121	122	0.72976	1.68464	100.182	042.468
77	122	123	0.22512	0.51968	142.523	060.417
78	123	124	0.20824	0.48071	096.042	040.713
79	124	125	0.04690	0.10827	300.454	127.366
80	125	127	0.61950	0.61857	141.238	059.873
81	127	128	0.34049	0.33998	279.847	118.631
82	128	129	0.56862	0.29911	087.312	037.013
83	128	130	0.10877	0.10860	243.849	103.371
84	130	131	0.56862	0.29911	247.750	105.025
85	0	133	0.01126	0.02598	000.000	000.000
86	133	134	0.41835	0.96575	089.878	038.101
87	134	135	0.10499	0.13641	1137.280	482.108
88	134	136	0.43898	1.01338	458.339	194.296
89	136	137	0.07520	0.02579	385.197	163.290
90	137	138	0.07692	0.17756	000.000	000.000
91	138	139	0.33205	0.76653	079.608	033.747
92	139	141	0.08442	0.19488	087.312	037.013
93	141	142	0.13320	0.30748	000.000	000.000
94	142	143	0.29320	0.29276	074.001	031.370
95	143	144	0.21753	0.21721	232.050	098.369
96	144	145	0.26482	0.26443	141.819	060.119
97	142	146	0.10318	0.23819	000.000	000.000
98	146	147	0.13507	0.31181	076.449	032.408
99	0	148	0.00938	0.02165	000.000	000.000
100	148	149	0.16884	0.38976	051.322	021.756
101	149	150	0.11819	0.27283	059.874	025.381
102	150	152	2.28608	0.78414	009.065	003.843
103	150	153	0.45587	1.05236	002.092	000.887
104	153	154	0.69600	1.60669	16.735	007.094
105	154	155	0.45774	1.05669	1506.522	638.634
106	155	156	0.20298	0.26373	313.023	132.694
107	156	157	0.21348	0.27737	079.831	033.842
108	157	158	0.54967	0.28914	051.322	021.756
109	158	159	0.54019	0.28415	000.000	000.000
110	157	160	0.04550	0.05911	202.435	085.815
111	160	162	0.47385	0.24926	060.823	025.784
112	162	163	0.86241	0.45364	045.618	019.338
113	163	164	0.56862	0.29911	000.000	000.000
114	158	200	0.77711	0.40878	157.070	066.584
115	200	201	1.08038	0.56830	000.000	000.000
116	159	202	1.09933	0.57827	250.148	106.041
117	202	203	0.47385	0.24926	000.000	000.000
118	154	204	0.32267	0.74488	069.809	029.593
119	204	205	0.14633	0.33779	032.072	013.596
120	205	206	0.12382	0.28583	061.084	025.894
121	0	207	0.01126	0.02598	000.000	000.000
122	207	208	0.64910	1.49842	094.622	046.260
123	208	209	0.04502	0.10394	049.858	024.375
124	209	210	0.52640	0.18056	123.164	060.214
125	209	211	0.02064	0.04764	078.350	038.304
126	211	212	0.53071	0.27917	145.475	071.121
127	211	214	0.09755	0.22520	021.369	010.447
128	214	215	0.11819	0.27283	074.789	036.564
129	214	217	0.13882	0.32047	227.926	111.431

130	217	218	0.04315	0.09961	035.614	017.411
131	218	219	0.09192	0.21220	249.295	121.877
132	219	220	0.16134	0.37244	316.722	154.842
133	220	221	0.37832	0.37775	333.817	163.199
134	221	222	0.39724	0.39664	249.295	121.877
135	222	223	0.29320	0.29276	000.000	000.000
136	7	86	0.13132	0.30315		
137	10	32	0.26536	0.13958		
138	20	130	0.14187	0.14166		
139	46	223	0.08512	0.08499		
140	33	61	0.04502	0.10394		
141	59	145	0.14187	0.14166		
142	65	147	0.14187	0.14166		
143	73	206	0.03940	0.09094		
144	78	125	0.12944	0.29882		
145	125	219	0.01688	0.03898		
146	131	223	0.33170	0.17448		
147	139	154	0.14187	0.14166		
148	138	217	0.07692	0.17756		
149	138	153	0.07692	0.17756		
150	141	154	0.07692	0.17756		
151	141	220	0.07692	0.17756		
152	145	206	0.26482	0.26443		
153	160	56	0.49696	0.64567		
154	212	122	0.17059	0.08973		
155	215	123	0.05253	0.12126		
156	223	147	0.29320	0.29276		

9- Eight-bus unbalanced Taiwan system[٩]

A sample system of 8 buses shown in Fig. 2 has been taken from the Taiwan Power Corporation. The base values of the system are 14.4 kV and 100 MVA.



Load data.

SL.NO.	BUS NO.	PHASE A (pu)	PHASE B (pu)	PHASE C (pu)
1.	2	0.519+0.250i	0.259+0.126i	0.515+0.250i
2.	3	0	0.259+0.126i	0.486+0.235i
3.	4	0	0	0.324+0.157i
4.	5	0	0	0.226+0.109i
5.	6	0	0	0.145+0.070i
6.	7	0.486+0.235i	0	0
7.	8	0	0.267+0.129i	0

Line data (self impedance).

SL.NO.	FROM	TO	PHASE A ($\times10^{-4}$ pu)	PHASE B ($\times10^{-4}$ pu)	PHASE C ($\times10^{-4}$ pu)
1.	1	2	7.74+3.33i	7.74+3.33i	7.74+3.33i
2.	2	3	0	12.9+5.55i	12.9+5.55i
3.	2	5	0	0	3.87+1.665i
4.	2	7	3.87+1.665i	0	0
5.	3	4	0	0	2.58+1.11i
6.	3	8	0	5.16+2.22i	0
7.	5	6	0	0	6.45+2.775i

Line data (mutual impedance).

NBR	BC ($\times10^{-4}$ pu)	AB ($\times10^{-4}$ pu)	AC ($\times10^{-4}$ pu)
1	2.58+1.11i	2.58+1.11i	2.58+1.11i
2	4.3+1.85i	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0

[٩] A modified Gauss–Seidel algorithm of three-phase power flow analysis in distribution networks.
Load Flow Analysis of Unbalanced Radial Distribution Systems.

10- 19-bus unbalanced radial distribution network[10]

A practical distribution feeder emanating from Pathardhi 132:11kV-grid substation in India. The network and load data are given in Tables 5–7. The r:x ratio for conductor type 1 is 2.32 and it is 3.52 for conductor type 2.One-line diagram if network has shown here. Sb = 1000 kVA & Vb = 11 kV.

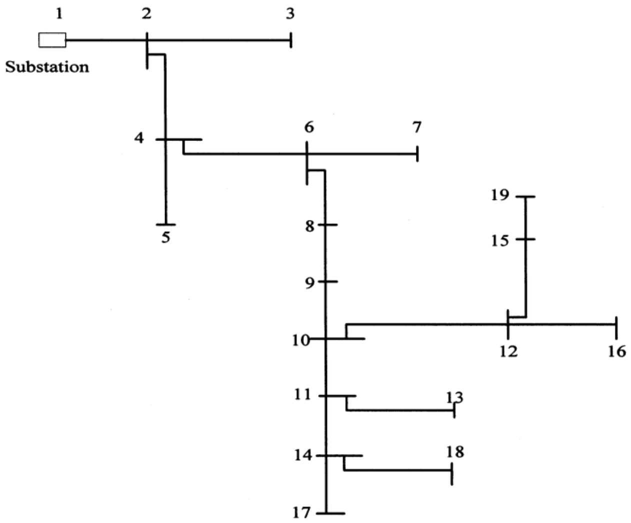


Fig. 5. A practical distribution feeder in India.

Here are the load data.

SL.NO.	BUS NO.	PHASE A (pu)	PHASE B (pu)	PHASE C (pu)
1.	2	0.01038+0.00501i	0.00519+0.00252i	0.01038+0.00501i
2.	3	0.01101+0.00534i	0.00519+0.00252i	0.00972+0.00471i
3.	4	0.00405+0.00195i	0.00567+0.00276i	0.00648+0.00315i
4.	5	0.00648+0.00315i	0.00519+0.00252i	0.00453+0.00219i
5.	6	0.00420+0.00204i	0.00309+0.00150i	0.00291+0.00141i
6.	7	0.00972+0.00471i	0.00810+0.00393i	0.00810+0.00393i
7.	8	0.00744+0.00360i	0.00534+0.00258i	0.00339+0.00165i
8.	9	0.01230+0.00597i	0.01491+0.00723i	0.01329+0.00642i
9.	10	0.00339+0.00165i	0.00420+0.00204i	0.00258+0.00126i
10.	11	0.00744+0.00360i	0.00744+0.00360i	0.01101+0.00534i
11.	12	0.00972+0.00471i	0.00810+0.00393i	0.00810+0.00393i
12.	13	0.00438+0.00213i	0.00534+0.00258i	0.00648+0.00315i
13.	14	0.00309+0.00150i	0.00309+0.00234i	0.00405+0.00195i
14.	15	0.00438+0.00213i	0.00486+0.00234i	0.00696+0.00336i
15.	16	0.00777+0.00378i	0.01038+0.00501i	0.00777+0.00378i
16.	17	0.00648+0.00315i	0.00486+0.00234i	0.00486+0.00234i
17.	18	0.00543+0.00258i	0.00534+0.00258i	0.00552+0.00267i
18.	19	0.00876+0.00423i	0.01005+0.00486i	0.00714+0.00345i

Line data (self impedance).

SL. NO.	FROM	TO	PHASE A (pu)	PHASE B (pu)	PHASE C (pu)
1.	1	2	0.0387+0.01665i	0.0387+0.01665i	0.0387+0.01665i
2.	2	3	0.0645+0.02775i	0.0645+0.02775i	0.0645+0.02775i
3.	2	4	0.01935+0.008325i	0.01935+0.008325i	0.01935+0.008325i
4.	4	5	0.01935+0.008325i	0.01935+0.008325i	0.01935+0.008325i

[10] Load Flow Analysis of Unbalanced Radial Distribution Systems
Load Flow Solution for Unbalanced Radial Power Distribution using Monte-Carlo Simulation
hpf36

5.	4	6	0.0129+0.00555i	0.0129+0.00555i	0.0129+0.00555i
6.	6	7	0.0258+0.0111i	0.0258+0.0111i	0.0258+0.0111i
7.	6	8	0.03225+0.013875i	0.03225+0.013875i	0.03225+0.013875i
8.	8	9	0.0387+0.01665i	0.0387+0.01665i	0.0387+0.01665i
9.	9	10	0.0645+0.02775i	0.0645+0.02775i	0.0645+0.02775i
10.	10	11	0.01935+0.008325i	0.01935+0.008325i	0.01935+0.008325i
11.	10	12	0.01935+0.008325i	0.01935+0.008325i	0.01935+0.008325i
12.	11	13	0.0645+0.02775i	0.0645+0.02775i	0.0645+0.02775i
13.	11	14	0.0129+0.00555i	0.0129+0.00555i	0.0129+0.00555i
14.	12	15	0.0645+0.02775i	0.0645+0.02775i	0.0645+0.02775i
15.	12	16	0.0774+0.0333i	0.0774+0.0333i	0.0774+0.0333i
16.	14	17	0.04515+0.019425i	0.04515+0.019425i	0.04515+0.019425i
17.	14	18	0.0516+0.0222i	0.0516+0.0222i	0.0516+0.0222i
18.	15	19	0.0516+0.0222i	0.0516+0.0222i	0.0516+0.0222i

Line data (mutual impedance).

NBR	BC($\times 10^{-3}$ pu)	AB($\times 10^{-3}$ pu)	AC($\times 10^{-3}$ pu)
1	12.9+5.55i	12.9+5.55i	12.9+5.55i
2	21.5+9.25i	21.5+9.25i	21.5+9.25i
3	6.45+2.775i	6.45+2.775i	6.45+2.775i
4	6.45+2.775i	6.45+2.775i	6.45+2.775i
5	4.3+1.85i	4.3+1.85i	4.3+1.85i
6	8.6+3.7i	0.09189+0.9314i	5.385+4.747i
7	10.75+4.625i	0.07351+0.7451i	4.308+3.797i
8	12.9+5.55i	12.9+5.55i	12.9+5.55i
9	21.5+9.25i	21.5+9.25i	21.5+9.25i
10	6.45+2.775i	6.45+2.775i	6.45+2.775i
11	6.45+2.775i	6.45+2.775i	6.45+2.775i
12	21.5+9.25i	21.5+9.25i	21.5+9.25i
13	4.3+1.85i	4.3+1.85i	4.3+1.85i
14	21.5+9.25i	21.5+9.25i	21.5+9.25i
15	25.8+11.1i	25.8+11.1i	25.8+11.1i
16	15.05+6.475i	15.05+6.475i	15.05+6.475i
17	17.2+7.4i	17.2+7.4i	17.2+7.4i
18	17.2+7.4i	17.2+7.4i	17.2+7.4i

Table 6
Branch data for the feeder shown in Fig. 5

From bus	To bus	Con. type	Length (km)	From bus	To bus	Con. type	Length (km)
1	2	1	3.00	10	11	1	1.50
2	3	2	5.00	11	14	1	1.00
2	4	1	1.50	11	13	2	5.00
4	5	2	1.50	14	17	1	3.50
4	6	1	1.00	14	18	2	4.00
6	7	2	2.00	10	12	1	1.50
6	8	1	2.50	12	16	2	6.00
8	9	1	3.00	12	15	1	5.00
9	10	1	5.00	15	19	1	4.00

Table 5
Conductor data

Conductor type	Conductor name	Resistance (PU/km)	Reactance (PU/km)
1	ACSRWSL	0.008600	0.003700
2	WEASAL	0.012950	0.003680

Base voltage = 11 kV, Base KVA = 1000

Table 7
Load data for the feeder shown in Fig. 5 under unbalanced condition

Node no.	Load in phase A (KVA)	Load in phase B (KVA)	Load in phase B (KVA)	Trans. capacity (KVA)	Node no.	Load in phase A (KVA)	Load in phase B (KVA)	Load in phase B (KVA)	Trans. capacity (KVA)
2	64.0	32.0	64.0	160	11	46.0	46.0	68.0	160
3	68.0	32.0	60.0	160	12	60.0	50.0	50.0	160
4	25.0	35.0	40.0	100	13	27.0	33.0	40.0	100
5	40.0	32.0	28.0	100	14	19.0	19.0	25.0	63
6	26.0	19.0	18.0	63	15	27.0	30.0	43.0	100
7	60.0	50.0	50.0	160	16	48.0	64.0	48.0	160
8	46.0	33.0	21.0	100	17	40.0	30.0	30.0	100
9	76.0	92.0	82.0	250	18	33.0	33.0	34.0	100
10	21.0	26.0	16.0	63	19	54.0	62.0	44.0	160

11-28-bus unbalanced Taiwan feeder''

Fig. 3 shows an 11.4 kV feeder acquired from Taiwan Power Company used in the following tests. Tables 1 and 2 are the load data and line length for this feeder, respectively.

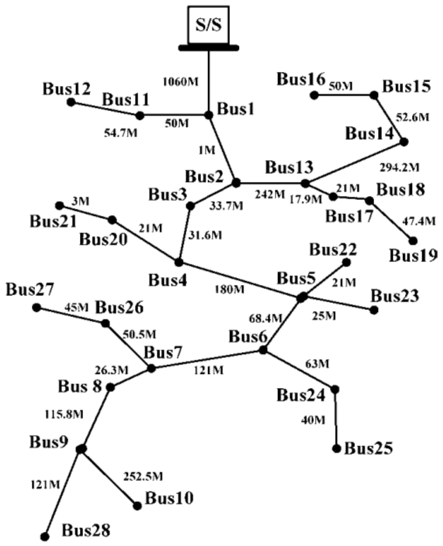


Figure 3 *Test feeder*

Table 1 Load data of test feeder

Bus number	Phase A		Phase B		Phase C	
	P, kW	Q, kVAR	P, kW	Q, kVAR	P, kW	Q, kVAR
1	139.9	90.4	31.9	20.6	31.9	20.6
2	0	0	0	0	0	0
3	28.4	48.3	56.0	– 0.4		
4	154.1	73.8	74.6	24.5	74.6	24.5
5	101.5	76.2	101.5	76.2	183.4	124.7
6			29.9	69.9	75.5	9.1
7	26.1	12.6	26.1	12.6	84.0	40.7
8			37.7	67.1	77.0	0.9
9	105.0	20.2	34.6	56.2		
10	84.0	63.0	84.0	63.0	141.5	98.7
11	113.2	61.1	113.2	61.1	212.4	109.1
12	165.1	91.3	81.4	46.1	81.4	46.1
13	367.3	133.3	367.3	133.3	367.3	133.3
14	30.5	13.9	30.5	13.9	108.9	58.3
15			75.3	85.9	88.8	– 6.5
16	20.5	33.2	104.6	39.6		
17	74.4	64.6	34.0	1.1		
18	67	44.8	14.2	0.2		
19			67.5	109.5	128.5	– 3.7
20	98.4	33.6	36.2	13.1	36.2	13.1
21	7.8	8.8	11.5	– 2.4		
22	29.9	16.1	73.9	49.1	29.9	16.1
23	173.7	68.3	72.1	34.9	72.1	34.9
24			47.9	– 3.5	75.4	69.7
25	88.2	23.2	26.0	48.5		

'' dpf03

26	75.7	19.0	75.7	19.0	207.0	51.9
27	23.5	1.2			87.2	66.3
28	79.5	49.3	79.5	49.3	187.7	130.4
total demand	2053.7	1046.2	1787.1	1088.4	2350.7	1038.2

Table 2 Line length of test feeder

Line number	From bus	To bus	Length, m
1	S/S	1	1060
2	1	2	1
3	2	3	33.7
4	3	4	31.6
5	4	5	180
6	5	6	68.4
7	6	7	121
8	7	8	26.3
9	8	9	115.8
10	9	10	252.5
11	1	11	50
12	11	12	54.7
13	2	13	242
14	13	14	294.2
15	14	15	52.6
16	15	16	50
17	13	17	17.9
18	17	19	21
19	18	19	47.4
20	4	20	21
21	20	21	3
22	5	22	21
23	5	23	25
24	6	24	63
25	24	25	40
26	7	26	50.5
27	26	27	45
28	9	28	121

12-A harmonic case study of a industry factory[۱۲].

The one-line digram of factory is shown here.

Fig. 1 shows the one-line diagram of the power system of a giant steel factory in Kaohsiung, Taiwan, which is served by a 161 KV double circuits directly from Taipower transmission system. The electricity demand contract is 145 MW. Besides buying electricity from Taipower, there are five cogenerators with a total capacity 208.6 MW to provide 60% of the electricity during the peak period. The cogenerators generate the electricity by exhausted gas during process to make full use of the resources and to increase the system reliability by providing the emergency power source for the critical loads. In the factory, there are 17 substations connected to utility by 161/33 kV transformers to supply the electricity to each plant.

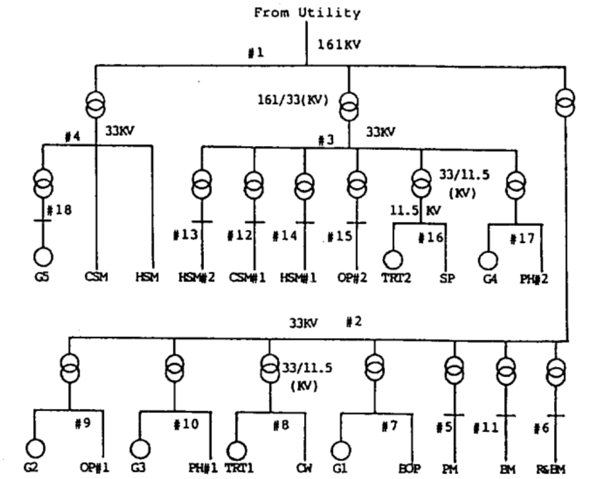


Fig. 1. The one-line diagram of studied power system.

Appendix A lists the input data used in the harmonic power flow program. It includes bus data, generator data, branch data, filter data and load composition data. Many converters are used in the hot strip mill (HSM), cold strip mill (CSM), and roll & bar mill (R&BM), to achieve automatic control of electromechanical systems. Due to these power electronic devices, a significant harmonic current is injected into the power system. For instance, the machines in the R&BM plant are driven by six-pulse converters during the production process from roughing stands, inter stands to finishing stand. Since the six-pulse converters produce harmonic currents of the order $6k \pm 1$, the dominant harmonic components in the system are the orders of 5, 7, 11, 13 and etc. The ac source transformers in a plant are installed with wye-delta and delta-wye alternatively to eliminate the harmonic components of the order $3n$.

[۱۲] Harmonic Analysis for Industrial Customers

TABLE VI
BUS DATA

BUS NAME	BUS NUMBER	LOAD TYPE	LOAD (Mw)	CAPACITOR (kvar)
161KV	1	1	.000	.000
T12	2	1	.000	.000
T34	3	1	6.000	.000
T56	4	9	51.913	.000
PM	5	2	5.528	.000
R&BM	6	3	9.864	.000
BOP	7	4	18.100	18.000
CW	8	1	27.200	11.540
OP#1	9	1	26.400	.000
PH#1	10	5	25.100	12.000
BM	11	6	7.634	.000
CSM	12	1	10.885	.000
HSM#2	13	1	30.504	.000
HSM#1	14	7	18.549	.000
OP#2	15	8	14.403	.000
SP	16	1	5.058	13.200
PH#2	17	1	26.800	18.000
SMG	18	1	.000	.000

TABLE VII
LOAD TYPE

Ltype	Linear load(%)	Nonlinear load(%)
1	95.80	4.20
2	81.10	18.90
3	44.33	55.67
4	95.30	4.70
5	98.03	1.97
6	95.52	4.48
7	61.79	38.21
8	96.00	4.00
9	7.90	92.10

TABLE VIII
BRANCH DATA

FBUS	TBUS	RL(P.U.)	XL(P.U.)
161KV	T12	.0021	.0982
161KV	T34	.0020	.0990
161KV	T56	.0019	.0991
T12	PM	.0194	.0214
T12	R&B	.0194	.0214
T12	BOP	.0195	.2122
T12	CW	.0195	.2147
T12	OP#1	.0195	.0978
T12	PH#1	.0212	.2641
T12	BM	.0195	.2147
T34	CSM#1	.0135	.2183
T34	HSM#2	.0135	.2221
T34	HSM#1	.0133	.2174
T34	OP#2	.0135	.2221
T34	SP	.0135	.2183
T34	PH#2	.0133	.2174
T56	SMG	.0039	.1353

TABLE IX
GENERATOR DATA

NAME	V(SPEC)	P(SPEC)	Q(MIN)	Q(MAX)	R1(P.U.)	X1(P.U.)
161KV	1.02	0.00	-100.0	100.0	0.000	0.200
SMG	1.00	61.87	-32.0	63.0	0.004	0.200
BOP	1.00	19.39	-12.0	19.0	0.004	0.169
OP#1	1.00	27.87	-17.0	28.0	0.004	0.236
PH#1	1.00	26.9	-17.0	28.0	0.004	0.236
PH#2	1.00	28.9	-16.0	31.0	0.004	0.164

TABLE X
FILTER DATA

BUS NAME	VOLTAGE	5TH		7TH		11TH	
	kV	kvar	mH	kvar	mH	kvar	mH
T56	7.6	1620.0	34.06	1620.0	17.37	3240.0	3.50
T56	7.6	1620.0	34.06	.0	.00	1620.0	7.03
PM	7.6	2970.0	1.87	.0	.00	.0	.00
R&BM	7.6	1890.0	3.57	1080.0	3.15	540.0	2.50
BM	7.6	.0	.00	.0	.00	540.0	1.87
CSM#1	7.6	2160.0	2.34	1620.0	1.93	540.0	1.93
HSM#1	7.6	2700.0	1.87	1080.0	2.39	.0	.00
HSM#2	7.6	3240.0	1.89	2700.0	.95	.0	.00

sd